Demystifying Extra Dimensions via 3D Lattice Dynamics

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Abstract：
This paper starts from the mapping of the time dimension in general relativity to the frequency and frequency gradient distribution of a 3D real-space lattice point network, exploring the viewpoint that all dimensions beyond the three spatial coordinates in higher-dimensional theories are actually dynamical degrees of freedom of spatial lattice points.

Introduction：
The world perceived by humans is a changing three-dimensional space. To cover more phenomena, the physics community has developed models such as the 4-dimensional spacetime of general relativity and the multi-dimensional spaces of string theory. How to understand these higher-dimensional theories more intuitively starting from the 3D space that people directly perceive has become a key issue in learning or teaching.

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Section 1. The Time Dimension

The 4D formalism of general relativity (GR) is abstract, while human cognition is 3D. Understanding the geometric time curvature of GR presents certain difficulties.

I provide an illustration:

1.1. We first understand GR from the perspective of 3D real space. GR is 4D diffeomorphism invariant. We impose a stronger constraint: 3D topological invariance — that is, the adjacency relations between spatial lattice points remain invariant. Under this constraint, there are no topologically singular solutions, i.e., no singularities.

1.2. Each lattice point possesses a harmonic oscillation degree of freedom (a simplified setting analogous to a phonon system; in reality, the degrees of freedom of spatial lattice points certainly include more than just harmonic oscillation, including spin and axial rotation degrees of freedom). The harmonic frequency of each lattice point represents the pace of its proper time. The distribution of harmonic frequencies of spatial lattice points constitutes the time curvature of GR.

1.3. GR assumes a continuous field; this harmonic oscillator system approximates that continuous field setting.

1.4. Based on gravitational redshift, cosmological expansion redshift, and the predictions of classical GR's gravitational time dilation relation, we can establish, within this model, a set of mirror relations between 3D geometric curvature and the harmonic frequencies of spatial lattice points. In this way, the geometric time curvature of GR is represented by the frequency distribution of spatial lattice points.

1.5. Within this physical model, the essence of electromagnetic waves is the transverse waves driven on this spatial lattice point network (which possesses spin, harmonic oscillation, and other degrees of freedom). The frequency of electromagnetic waves is the frequency of the spatial lattice points, and since the frequency of electromagnetic waves is related to energy($E=h\nu$), the frequency of spatial lattice points can also represent energy.

Thus, all geometric dynamical effects related to the time component in general relativity can be fully represented by the frequency scalar field of this three-dimensional harmonic oscillator system and its gradient. The time geometry in the 4D formalism of general relativity corresponds precisely to the frequency gradient distribution of spatial lattice points in 3D space.

At this point, readers can see: the direct relationship between the time geometry of relativity and energy? Doesn't this explain abstract 4D Riemannian geometry using intuitive 3D geometry plus a frequency distribution on space?

Section 2. Other Dimensions

2.1. The understanding in physics that higher dimensions beyond 3D spatial coordinates can be interpreted as additional degrees of freedom of spatial lattice points has a long history. For example, Kaluza-Klein theory has suggested that compactified extra spatial dimensions manifest at low energies as internal degrees of freedom of particles (such as charge, spin) (Overduin & Wesson, 1997)[1]. Spin networks in loop quantum gravity (Rovelli & Smolin, 1995)[2] have quantized spatial geometry into degrees of freedom on nodes and links. Noncommutative Geometry and Physics (Connes, 2006)[3] and

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dualities in string theory (Seiberg & Witten, 1999)[4] have demonstrated technical pathways through which spatial dimensions transform into internal degrees of freedom under specific limits. As argued by Einstein (1920)[5] and Wilczek (2008)[6], space is not an empty container but a medium with physical properties. Laughlin (2005)[7] further argued from an emergent perspective that physical laws can be the result of collective behavior of a medium. Within this philosophical framework, this paper proposes that the degrees of freedom of a 3D lattice point network can fully reproduce the physical content of higher-dimensional theories—all extra dimensions are no longer extensions of space, but rather local dynamical degrees of freedom of lattice points on the 3D spatial network.

2.2. In the process of previously attempting to construct a quantized elastic spacetime model [8] with a 3D topologically invariant adjacency network that can cover all known phenomena, the author discovered that by endowing the spatial network lattice points (Space Elementary Quanta SEQ)with harmonic oscillation, spin with fixed chirality, axial rotation, and spacing and stress modulation of stretching and compression between lattice points, one can cover the interactions described by the three major Lie groups of gauge symmetry, as well as gravitational interactions—achieving an effect equivalent to string theory covering more interactions through higher dimensions. In considering the reduction of GR's time geometric curvature to the harmonic frequency gradient distribution of spatial lattice points, the author asks: is the essence of the higher dimensions required by string theory to cover phenomena precisely the introduction of more local dynamical degrees of freedom of spatial lattice points?

The gauge symmetries (U(1), SU(2), SU(3)) defined on Hilbert space in quantum field theory can, within this model, be understood as local interactions between adjacent quanta on the 3D spatial lattice point network. The feasibility of this mapping is based on the following physical intuitions:

2.2.1. U(1) — Electromagnetic Interaction

Corresponds to resonant phase synchronization on the SEQ network. The resonant phase difference between adjacent SEQs drives transverse wave propagation. The essence of electromagnetic waves is the phase-coherent transverse waves driven on this network. The electric field corresponds to the gradient of the harmonic amplitude, while the magnetic field originates from the spatial twist (twistor) induced by SEQ spin.

2.2.2. SU(2) — Weak Interaction

Corresponds to the rotation axis and chirality encoding of the structural matrix of charged microscopic particles. Since the ground-state spin of SEQ has fixed chirality, structural matrices of charged particles with different chiralities couple differently to it. This asymmetry constitutes the geometric origin of parity violation in weak interactions. The double covering property of SU(2) (the double cover of SO(3)) acquires an intuitive image within this framework: the electron's spin and spin-axis flipping period are synchronized, achieving a 4π reset.

2.2.3. SU(3) — Strong Interaction

Corresponds to the local compression dynamics of the SEQ network. Quark confinement originates from the nonlinear elastic response of the SEQ network and Higgs chiral locking mechanism in a compressed state. Asymptotic freedom corresponds to the asymmetric attenuation of compression-stretching elastic coefficients in the high-energy limit. The fractional charges of quarks

originate from the dynamic phase coherence of different shells in the layered structure of protons/neutrons—quarks carrying 2/3 charge occupy twice the number of layers as those carrying 1/3 charge.

The three gauge interactions described above are not independent fundamental forces, but rather different excitation modes of the same 3D lattice point network: compression mode corresponds to SU(3), rotation/chirality mode corresponds to SU(2), and harmonic oscillation/lattice point spin phase synchronization mode corresponds to U(1). This perspective reduces gauge symmetries to local dynamical rules between adjacent lattice points, consistent with the spirit of lattice gauge theory.

2.3. Wilson (1974), in his foundational work on lattice gauge theory [9], discretized the gauge field of continuous spacetime into correlation variables on lattice links, with the gauge potential corresponding to phase factors (group elements) between adjacent lattice points. Gauge symmetry becomes a redundant degree of freedom on local links. In Kogut's (1979) classic review [10], it is detailed that in lattice QCD, quark fields are defined on lattice points and gauge fields on links. All physical processes are completely determined by the interactions between adjacent lattice points.

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